

# DEVELOPMENT AND APPLICATION OF SPACE INFLATABLE STRUCTURES

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## ABSTRACT

Space inflatable structures technology is one of the emerging technologies that can potentially revolutionize the designs and applications of large space structural systems. Many of the NASA missions planned for the next decade will need space inflatable structures to achieve their launch volume and mass goals. This is especially true for missions employing spacecraft equipped with certain types of hardware components and systems that require relatively large in-orbit configurations for proper performance of their assigned functions. These include radar antennas, solar arrays, sunshades, solar concentrators, and telescope reflectors. At present, these hardware components and systems commonly employ mechanically deployed structures to meet launch volume constraints imposed by the fairing size. Compared to mechanically deployable structures, space inflatable structures have several distinct advantages, including much lighter weight, higher packaging efficiency, lower life-cycle costs and, most importantly, simpler design that leads to less parts count and higher deployment reliability. It is inevitable that, for many space applications inflatable structures will replace mechanically deployed structures in the foreseeable future.

Depending on how stringent the configuration accuracy requirement is for its intended application, a space inflatable structure may fall into one of the two roughly defined groups: hi-precision and low-precision. At this time, precision inflatable structures refer mainly to large apertures, such as telescope reflectors that operate in the near-infrared and visible wavelengths. These reflectors require not only large apertures, but also hi-precision reflective surfaces that have extremely small configuration errors in the micron or even sub-micron range. Before these large-aperture precision reflectors can be actually used for space missions, many technical challenges must be overcome, including high-quality thin films, reflective coatings on films, hi-precision manufacturing and assembly techniques, hi-precision ground measurements, and in-orbit configuration control methods. On the other hand, the low-precision inflatable structures cover a wide range of structural systems formed by tubular elements. These are the more traditionally structural elements of beams, columns, planar frames, and space trusses for applications of radar arrays, solar arrays, sunshield, and radio-frequency reflectors, etc. Although there also are technical challenges to be overcome for these low-precision inflatable structures, it is believed that their applications to space missions can be achieved in the foreseeable future.

The major technology development needs for low-precision applications of space inflatable structures are inflation deployment control and stability, space rigidization, analysis and simulation tools, materials characterization space survivability, and innovative application concepts. In the past several years, researchers in NASA, other government agencies, industry, and academia have been addressing these technology needs in the confine of near-term applications of low-precision space inflatable structures. Various mechanical designs are being created, studied, and test-verified for packaging inflatable structures and controlling inflation

deployment. Noticeable progresses are being made in the development of space rigidizable materials and resins, including thermal-set, thermal plastic, UV-curable, hydro-gel, stretched aluminum laminates, and reinforced aluminum laminate. Analysis and simulation methods are also being developed for predicating dynamics of inflation deployment, modal behaviors of large, wrinkled membranes, formation of wrinkles in tensioned thin-films, and shape changes of adaptive inflatable reflectors. Many of the research results have been successfully demonstrated during ground testing of engineering models. Additionally, several space demonstration missions have been proposed and planned to enhance the readiness of space inflatable structures technology for near-term, low-precision applications. These include the Inflatable Sunshield in Space (ISIS) and the Inflatable Synthetic-Aperture Radar (ISAR) Missions.

The ISIS Mission is one of the pathfinder missions that are being planned as a part of on-going NASA effort to develop key technologies for the Next Generation Space Telescope (NGST). The NGST (see Figure 1), which will be launched around 2010 as the replacement for the Hubble Space Telescope will be operating at L2 and requires a lightweight sunshield of a 32m x 18m aperture and multiple layers of thin-film membranes. After extensive system design trade studies, it was concluded that an inflatable NGST sunshield could be an attractive option if several technical concerns could be appropriately addressed. One of these is unintentional contact of the inflating sunshield structure with the 8-m foldable telescope mirror located in its near vicinity. To eliminate this particular concern, a 1/2-scale engineering model of the inflatable NGST sunshield was developed and ground-tested to successfully demonstrate that if properly designed, the deployment of large inflatable structures can be accurately controlled and predicated. The planned ISIS Mission will focus on addressing two other major NGST concerns: (1) the lack of space flight data to verify dynamic modeling of large structural systems dominated by tensioned thin-film membranes, and (2) feasibility of in-space rigidization of inflatable structures. Figures 2a, 2b, and 2c show the 1/2-scaled engineering in the stowed, deploying, and fully deployed configurations, respectively. Currently, ISIS is under development and scheduled to be flown in the Space Shuttle in early 2001.

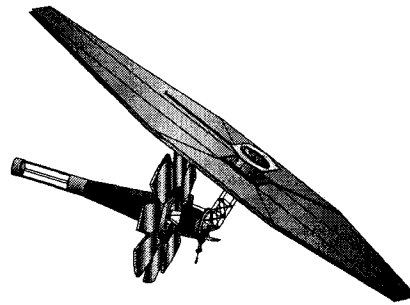
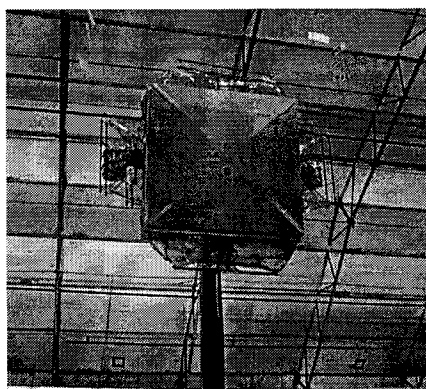


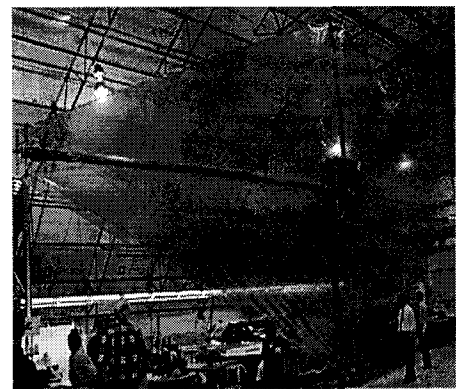
Figure 1. NGST Reference Architecture



(a) Stowed



(b) Deploying



(c) Fully Deployed

Figure 2. Deployment test of A 1/2-scaled NGST Inflatable Sunshield Engineering Model

The ISAR space demonstration, on the other hand, represents a major step in NASA's effort to reduce life-cycle costs of earth-observing missions employing synthetic-aperture radars (SAR). Traditionally, several solid RF panels that are folded up at launch form a SAR radar antenna and deployed in space by motor-driven mechanisms, e.g., Canada's RADARSAT shown in Figure 3 is one of the recently launched that has this traditional architecture. The mass of these panels is in the order of tens of kilograms per square meter of aperture area and their launch volume is very large in at least two dimensions. The combined effect of antenna mass and volume leads to the need of large and costly launch vehicles. In 1996, researchers at the Jet Propulsion Laboratory, working under (ARTP) sponsored by NASA, conceived and developed an inflatable rolled-up SAR array (see Figures 4a and 4b) that are lightweight and have an extremely high packaging efficiency. Two 1/3-scale engineering model were built and RF-tested

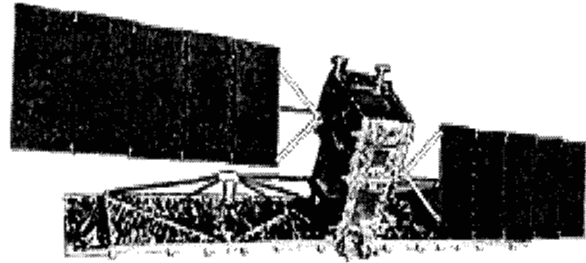
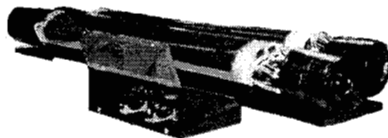
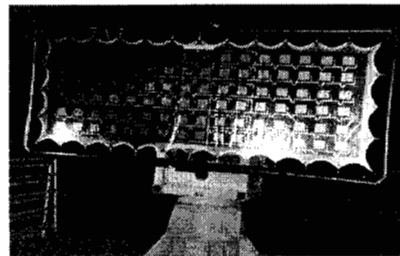


Figure 3. Canada's RADARSAT



(a) Stowed



(b) RF Testing

Figure 4. Inflatable Rolled-Up SAR Antenna Array

to verify that the inflatable SAR arrays are functionally comparable to antenna arrays formed by solid panels. Over the past three years, significant improvement have been made on the design of inflatable SAR arrays, especially in the area of space rigidization of the inflatable structures. It is felt that the time has come to plan for a space mission that will not only demonstrate the readiness of using inflatable arrays in future SAR missions, built also obtain meaningful science data. Currently, ISAR is still in the early planning stage; however, it is hoped that it can be launched in 2003.

This paper will summarize the current state-of-the-art of space inflatable structures technology and presents a vision for its future applications and development.